Water Use and Biomass Production of Oat–Pea Hay and Lentil in a Semiarid Climate

J. L. Pikul, Jr.,* J. K. Aase, and V. L. Cochran

ABSTRACT

Suitability of alternative crops in the northern Great Plains remains a question because of water limitations. Objectives were to compare water use of an oat (*Avena sativa* L.)–pea (*Pisum sativum* L.) mix grown for hay (OPH) to that of black lentil (*Lens culinaris* Medikus cv. Indianhead) grown as green manure (BL). Water use and plant biomass for OPH and BL were measured near Culbertson, MT (Site 1), during 4 yr. Soil water was measured by neutron attenuation. Precision-weighing lysimeters were used at Site 2, located 65 km southeast of Site 1, to measure water use. Soil was a Williams loam (fine-loamy, mixed, superactive, frigid Typic Argiustolls). Biomass of crops was measured biweekly. Relative feed value (RFV) based on measured neutral detergent fiber and acid detergent fiber was calculated. Biomass under OPH was 34 and 46% greater than with BL at Sites 1 and 2, respectively. At Site 1, biomass accumulated at a rate of 14 kg ha^{-1} mm^{-1} water used under BL and 23 kg ha^{-1} mm^{-1} under OPH. Biomass accumulated at a rate of 21 kg ha^{-1} mm^{-1} under BL and 29 kg ha^{-1} mm^{-1} under OPH at Site 2. Hay RFV, at full bloom in pea, averaged 116 (Number 2 hay), and this did not change appreciably as the crop matured to soft dough stage in oat. Oat–pea hay fits the growing conditions in the northern Great Plains and meets the needs of producers for high quality hay.

Water limits crop production in the semiarid northern Great Plains, and consequently, cropping options are limited. Wheat (*Triticum aestivum* L.) is the major crop in Montana, accounting for nearly 58% of all crop receipts in 2000 (Montana Agric. Stat. Serv., 2001). There were about 1.9 million ha of wheat (70% spring wheat) in Montana in 2000, all being nonirrigated. Nearly 70% of that wheat was produced on land following fallow. Because of climatic, economic, or cultural constraints, summer fallow is still a common practice. Fallow has accelerated soil C loss (Rasmussen and Parton, 1994; Aase and Pikul, 1995), soil erosion (especially where there are meager amounts of crop residue cover), and development of saline seeps (Black et al., 1981). Soil water storage efficiency of fallow ranges from about 15 to 40% (Black and Power, 1965; Tanaka and Aase, 1987; Peterson et al., 1996). However, even with low water-storage efficiency, rotations that included fallow were found to have the lowest level of financial risk (Zentner et al., 2001). Johnson (1982) found that income variability was reduced under summer fallow and that summer fallow maximized return to land at low yields, low wheat prices, and high N prices.

Progress in crop breeding and management coupled with desire to improve economic advantages of crop rotations have resulted in attempts to establish new rotations in traditional fallow–grain production areas (Campbell et al., 2002). Legumes have historically been included in crop rotations. Concern over loss of soil organic matter and cost of fertilizer N prompted a rediscovery of green-manure crops for semiarid wheat production systems even in light of the literature base that suggested green-manure farming systems were not profitable in the Dakotas and Canadian Prairie Provinces (Pieters, 1917). Conclusions from studies started in Montana in the early 1900's and reported after 28- and 43-yr periods (Army and Hide, 1959) were similar to the conclusions drawn by Pieters (1917). However, recent studies on the Canadian Prairies show that annual legumes have potential as green-manure crops (Rice et al., 1993). In grain lentil–wheat rotations, there has been a gradual reduction in fertilizer N requirement after about 6 yr (Campbell et al., 1992). Pikul et al. (1997) concluded that available N limited wheat production more than did soil water in rotations where green manure was the sole source of N. Black lentil has been identified as having good potential as a green manure because of low seed cost, intermediate top growth, and N yield (Townley-Smith et al., 1993).

Suitability of alternative crops and rotations in the traditional semiarid wheat production areas remains a question. Annual legume species have different N fixation capabilities and water use efficiencies. Biederbeck and Bouman (1994) tested water use characteristics of BL, Tangier flat pea (*Lathyrus tingitanus* L.), chickling vetch (*Lathyrus sativus* L.), and feed pea. Annual legumes that produce high quantities of phytomass had water use efficiencies that were greater than legume species that produced less phytomass. Feed pea and chickling vetch used water more efficiently than other legumes tested. Green manure may ultimately improve soil condition; however, costs associated with this prac-

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Published in Agron. J. 96:298–304 (2004).

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Abbreviations: ADF, acid detergent fiber; BL, black lentil grown as a green manure; CV, coefficient of variation; ET, evapotranspiration; GDD, growing degree days; NDF, neutral detergent fiber; OPH, oat–pea mix grown for hay; RFV, relative feed value; SW–BLc, spring wheat–black lentil rotation where black lentil was terminated by chemical; SW–BLd, spring wheat–black lentil rotation where black lentil was terminated by disking; SW–CF, 2-yr rotation of spring wheat–chemical fallow (no tillage during fallow); SW–OPH, 4-yr rotation of spring wheat–buckwheat–fallow–oat/pea mix grown for hay; WW–OPH, 4-yr rotation of winter wheat–buckwheat–fallow–oat/pea mix grown for hay.

tice may outweigh perceived benefits (Vigil and Nielsen, 1998; Pikul et al., 1997).

Aase and Pikul (2000) report water use characteristics of rotations having customary and alternative crops in eastern Montana. The current paper deals with growing season water use and biomass production. Briefly, Aase and Pikul (2000) found that total water use differed only slightly among rotations at the end of each 4-yr rotation cycle. Results suggested that soil water storage rapidly reached an upper drained limit (Aase and Pikul, 2000). Independent water infiltration and drainage tests (Pikul and Aase, 2003) supported that conclusion. Thus, strategies for efficient water use should focus on utilization rather than storage. A rotation that included OPH seemed to fit the needs of producers in the northern Great Plains because of the potential to improve soil condition with a legume in rotation and a regional demand for high quality forage (Aase and Pikul, 2000). Objectives of this study were to compare growing season water use and biomass production of OPH with that of BL.

MATERIALS AND METHODS

Field experiments were conducted at two sites. Site 1 was located 11 km north of Culbertson, MT. Site 2 was located 65 km southeast of Site 1. Soil at both locations is a Williams loam. Slope at Site 1 is about 3%, and there is no appreciable slope at Site 2. Average annual precipitation at both locations is about 340 mm, with about 80% occurring between April and September. Both Sites 1 and 2 have similar crop production capabilities. For example, median spring wheat yield (1983–1991) for wheat–fallow rotation was 1730 kg ha^{-1} (SD = 900 kg ha^{-1}) at Site 1 and 1750 kg ha^{-1} (SD = 800 kg ha^{-1}) at Site 2. At both Sites 1 and 2, OPH follows fallow and BL follows spring wheat.

Soil at both locations developed from glacial till, and there is considerable variability in subsoil texture; consequently, there is considerable variability in soil water storage capacity. For example, at Site 1, we found that sand content at the 0.6- to 0.9-m depth varied from 254 to 829 g kg^{-1}, and water content varied from 21 to 101 mm across a 100- by 250-m field. Crop water use at Site 1 was estimated using measured precipitation and soil water content (water balance method) on replicated plots. Crop water use at Site 2 was measured using precision-weighing lysimeters.

Site 1—Replicated Plot Studies

Before the start of the experiment in 1991, wheat was grown in a fallow–spring wheat rotation with no fertilizer. Soil P levels were built up by broadcast application of 45 kg P ha^{-1} as diammonium phosphate [$(NH_4)_2HPO_4$, 18–46–0 N–P–K] and 40 kg P ha^{-1} as triple superphosphate [$3Ca(H_2PO_4)_2$, 0–44–0] at the start of the experiment following recommendations proposed by Black (1982). Experimental design was a randomized complete block with four replications and five rotations (Table 1). Plots were 12 m wide and 15 m long. Each rotation was arranged so that every crop (or phase) of each rotation was present every year for a total of 56 plots.

Two treatments were in a 2-yr rotation of spring wheat (SW)–green manure. During part of the summer portion of the fallow year, BL was terminated either mechanically by disking (SW–BLd) or by chemicals (SW–BLc). A mixture of glyphosate [(*N*-phosphonomethyl)glycine] and 2,4-D (2,4-dichlorophenoxyacetic acid) was used to kill BL on SW–BLc. Glyphosate was applied at 2.3 L ha^{-1}, and 2,4-D was applied at 0.54 kg ha^{-1}. On SW–BLc, BL was no-till-seeded. On SW–BLd, the seedbed was prepared for BL similarly to that for spring wheat. Both green-manure treatment plots were seeded at about 59 kg ha^{-1} using a John Deere 750 No-Till Drill with 0.19-m row spacing. Seeding date was as early as 20 April and as late as 21 May (Table 2). In 1992 and 1993, BL was killed at about full bloom (normally mid-July). In 1994 and 1995, BL was killed shortly after pods were set in the lower portion of the plant (Table 2). No inorganic fertilizer was applied to the green-manure plots.

Table 1. Rotations with black lentil grown as a green manure (BL), spring wheat (SW), winter wheat (WW), and oat–pea hay (OPH) at Site 1 and 2. At Site 1, all phases of each rotation were present each year, and the crop rotations are exemplified by rotation sequences starting in 1992. For example, cropped and noncropped plots in 1992 for the 4-yr SW–OPH rotation include buckwheat, fallow, OPH and SW.

Rotation	Abbreviation†	1992	1993	1994	1995	1996
			Site 1			
1) 2 yr	SW–BLd	BL	SW	BL	SW	
2) 2 yr	SW–BLc	BL	SW	BL	SW	
3) 4 yr	SW–OPH	buckwheat	fallow	OPH	SW	
4) 4 yr	WW–OPH	buckwheat	fallow	OPH	WW	
5) 2 yr	SW–CF	fallow	SW	fallow	SW	
			Site 2			
	north lysimeter		BL	fallow	OPH	fallow
	south lysimeter		fallow	BL	fallow	OPH

† BLd, black lentil terminated by disking; BLc, black lentil terminated by chemical; CF, chemical fallow.

A mix of oat and pea was seeded for hay (OPH). Two treatments involved a 4-yr rotation of wheat–buckwheat (*Fagopyrum esculentum* Moench)–fallow–OPH with conventional tillage. Spring wheat was used in rotation SW–OPH and winter wheat was used in rotation WW–OPH (Table 1). We aimed for a ratio (viable seeds) of about 200 oat seeds to 100 pea seeds per square meter following recommendations of Chapko et al. (1991) and Cole (1989). Actual seeding rate, on a mass basis, varied year to year depending on seed weight of cereal and pea. In 1992, 1993, 1994, and 1995, we seeded OPH at a rate of 130, 133, 127, and 134 kg ha^{-1}, respectively. This mix provided 70, 74, 78, and 80 kg pea ha^{-1} in 1992, 1993, 1994, and 1995, respectively. Before seeding, OPH plots received 34 kg N ha^{-1} broadcast as NH_4NO_3. Pea and BL were inoculated with Sow-Fast (Loveland Industries, Greely, CO) inoculant using 35 g of inoculant to 23 kg of seed. Typically, OPH was cut when oat was in the soft dough stage, but others have cut when the cereal was in the milk growth stage (Carr et al., 1998).

Table 2. Seeding and termination dates for black lentil and oat–pea hay at Sites 1 and 2. Growing degree days and precipitation for 1 May through 31 July.

	1992	1993	1994	1995	1996
			Site 1		
Black lentil seeded	28 April	10 May	20 April	2 May	
Black lentil terminated	17 July	30 July	20 July	26 July	
Oat–pea hay seeded	3 April	13 May	9 May	3 May	
Oat–pea hay terminated	13 July	15 July	18 July	24 July	
Growing degree days, °C	946	867	1052	1038	
Precipitation, mm	180	217	169	187	
			Site 2		
Black lentil seeded		14 May	5 May		
Black lentil terminated		17 August	28 July		
Oat–pea hay seeded				3 May	3 June
Oat–pea hay terminated				25 July	1 August
Growing degree days, °C		949	1139	1059	1409
Precipitation, mm		339	235	214	154

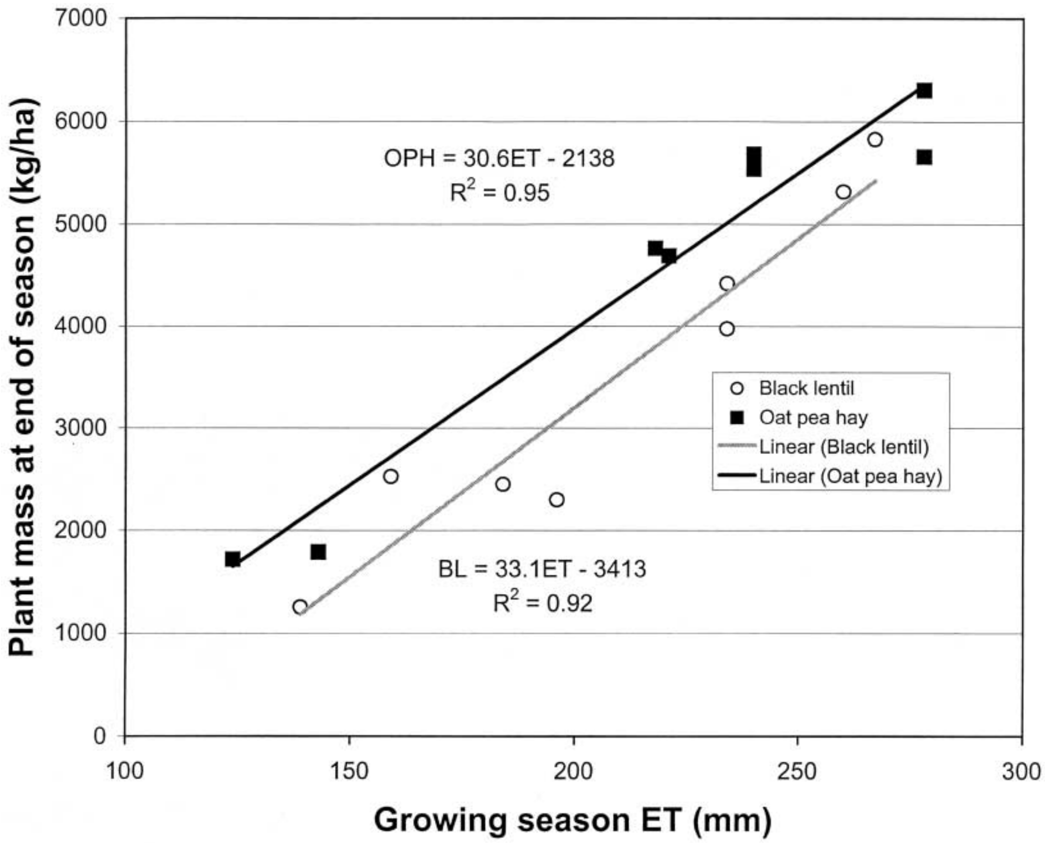

Fig. 1. Growing season evapotranspiration (ET) and plant mass (at final harvest) for black lentil grown as a green manure (BL) and oat–pea hay (OPH) at Site 1 for years 1992–1995. The linear regression model for plant mass production as a function of growing season ET was significantly ($P = 0.05$) different between BL and OPH.

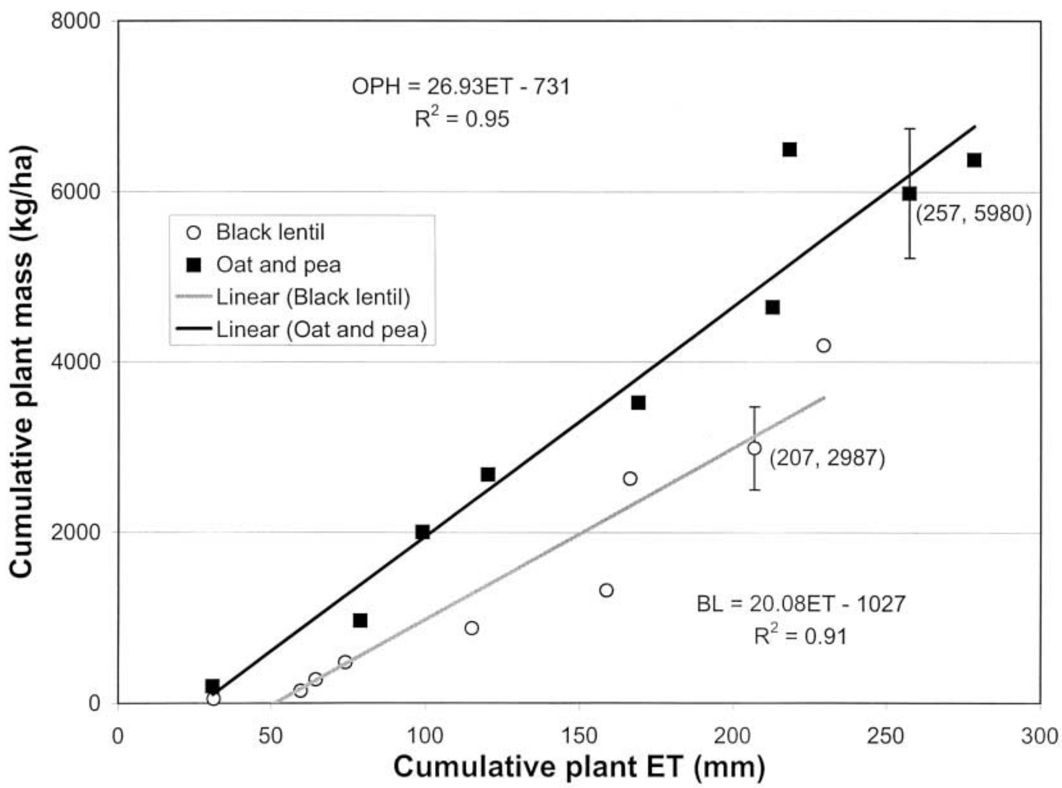

Fig. 2. Cumulative evapotranspiration (ET) and plant mass for black lentil grown as a green manure (BL) and oat–pea hay (OPH) at Site 1 (soil water balance studies) during 1995. Error bars show ±1 standard deviation at 75 d after planting. The linear regression model for cumulative plant mass production as a function of cumulative ET was significantly ($P < 0.001$) different between BL and OPH.

One treatment was a 2-yr rotation of spring wheat–chemical fallow (SW–CF) (Table 1). The same chemicals used to terminate BL were used as necessary to eliminate weeds on SW–CF plots. Water use during fallow served to compare water use under BL and OPH.

Water use was measured using neutron attenuation at about 14-d intervals to a depth of 1.8 m at 0.30-m increments. Access tubes for these measurements were located in the center of each plot. Water use, which is combined evaporation and transpiration water loss, was calculated for each interval as:

$$\text{Water use} = \text{rain} - (\text{soilwater}_2 - \text{soilwater}_1) \quad [1]$$

where rain is the amount of precipitation occurring between 14-d soil water measurements termed soilwater_1 and soilwater_2. Soil water is the depth of water in the 1.8-m soil profile at each 14-d measurement. Growing season water use for both crop and fallow was the sum of 14-d water use for appropriate time intervals. Growing season water use under BL or OPH was measured from seeding date to termination of crop. Calculations are based on the assumption that there was equal water runoff (or runon) and deep water drainage from the plots.

Biomass of BL and OPH were obtained by cutting plant samples at soil level from two adjacent 0.5-m-long rows at two locations on each plot. Samples were taken at about the same time as biweekly soil water measurements. Additional samples at harvest (Table 2) were taken on OPH by cutting a swath 1 by 2.93 m. All plant samples were oven-dried (60°C), and biomass was expressed on a dry weight basis. Subsamples were ground to pass a 2-mm sieve, and forage crude protein, neutral detergent fiber (NDF), and acid detergent fiber (ADF) were measured at Dairyland Laboratories (Acadia, WI). Relative feed value of forage was calculated following the methods of Linn and Martin (1989). Relative feed value is an index that combines NDF and ADF into one number and has been used to evaluate forage quality of alfalfa (*Medicago sativa* L.) (Becker et al., 1998; Kuehn et al., 1999) and legumes, grasses, and legume–grass mixtures (Linn and Martin, 1989).

Site 2—Weighing Lysimeter Studies

We used two precision-weighing lysimeters, 1.68 by 1.68 by 1.83 m deep to measure evapotranspiration (ET) and fallow evaporation hourly. Design of these lysimeters was similar to that described by Ritchie and Burnett (1968) and further described by Aase et al. (1996). Lysimeters were in the middle of adjacent 180- by 180-m fields, termed north and south, and these fields were used in rotation for crop and chemical fallow (Table 1).

Seeding rates and management of BL and OPH at this site followed the methods described for Site 1. In 1995 and 1996, we seeded OPH at a rate of 134 kg ha^{-1}, and this mix provided 80 kg pea ha^{-1}. To avoid damaging the lysimeter-weighing mechanism, we seeded BL and OPH on the lysimeter and on an area approximately 0.6 m wide surrounding the lysimeter by hand. We seeded these areas at a high rate and then thinned the population to match that on the surrounding field. Oat–pea was thinned on the lysimeter so that plant density and ratio of oat to pea matched that of the surrounding field. For example, in 1995, the surrounding field had 300 oat plants and 100 pea plants per square meter, and the lysimeter was thinned

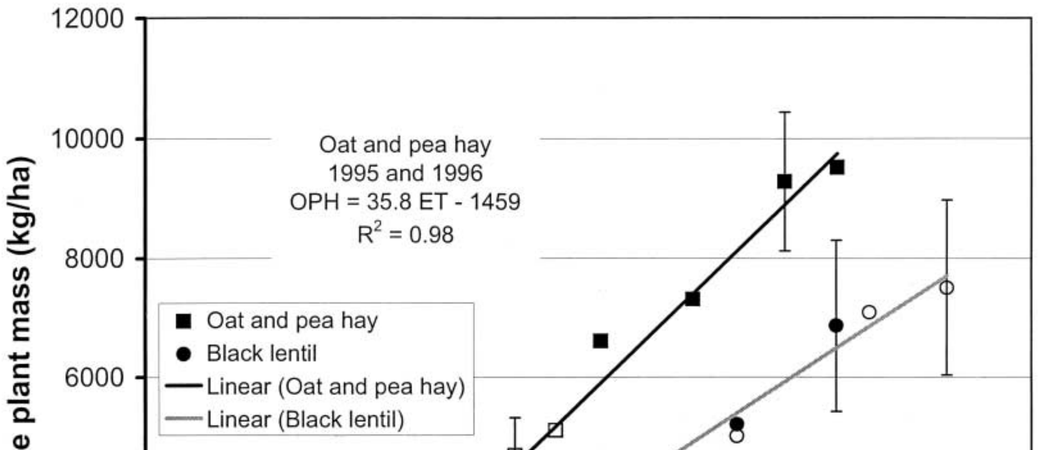

Fig. 3. Cumulative evapotranspiration (ET) and plant mass for black lentil grown as a green manure (BL) during 1993 and 1994 and oat–pea hay (OPH) during 1995 and 1996 at Site 2 (precision-weighing lysimeter studies). Error bars show ±1 standard deviation at the end of the growing season for each of 4 yr. Open symbols identify data points for 1994 and 1996. The linear regression model for cumulative plant mass production as a function of cumulative ET was significantly ($P = 0.05$) different between BL and OPH.

to match this density and ratio of oat to pea. Plant biomass was measured at about 14-d intervals on subplots adjacent to the lysimeter.

At both sites, growing degree days (GDD) were accumulated from date of seeding using a base temperature (Tb) of 5°C

$$\text{GDD} = \Sigma\,[(\text{Tmax} + \text{Tmin})/2 - \text{Tb}] \quad [2]$$

where Tmax is daily maximum air temperature (°C) and Tmin is minimum air temperature (°C). Water use and yield were tested for significant differences among treatments using analysis of variance and least significant differences (LSD) at P = 0.05. Lentil top growth (Rotations 1 and 2) and OPH top growth (Rotations 3 and 4) were compared using analysis of variance. Linear regression analysis was used where appropriate, and the methods of Neter et al. (1990) were used to test for significant (P = 0.05) differences between regression lines.

RESULTS AND DISCUSSION

At Site 1, growing season water use for 1992 through 1995 averaged 209 mm for BL and 218 mm for OPH. Average water loss under chemical fallow during the growing season was 144 mm. Average plant mass for BL was 3510 kg ha^{-1} [coefficient of variation (CV) = 46%] and 4520 kg ha^{-1} for OPH (CV = 39%). Plant mass at the end of the growing season and crop ET to produce that mass are shown in Fig. 1. Slope of the regression line represents an average seasonal rate of biomass accumulation per millimeter of ET. Regression analysis showed a significant (p = 0.001) relation between plant mass at the end of the growing season and growing season ET for both BL and OPH. Slope was 33.1 kg ha^{-1} mm^{-1} (SD = 3.9) for BL and 30.6 kg ha^{-1} mm^{-1} (SD = 2.8) for OPH. For comparison, average spring wheat yield of grain for 1992–1994 (wheat was damaged by hail in 1995) was 3285 kg ha^{-1} (CV = 15%), and ET was 320 mm (data not shown).

Plant dry matter accumulation and cumulative ET during the 1995 growing season are shown in Fig. 2 for BL and OPH at Site 1. There was a significant (p = 0.001) linear relation between dry matter accumulation and cumulative ET for both BL and OPH. Slope of the regression line was 20.1 kg ha^{-1} mm^{-1} (SD = 2.4) for BL and 26.9 kg ha^{-1} mm^{-1} (SD = 2.4) for OPH. At 75 d after planting, cumulative ET was 207 mm for BL and 257 mm for OPH. Accumulated plant mass was 2990 kg ha^{-1} under BL and 5980 kg ha^{-1} under OPH, which was significantly (p = 0.001) different.

We found a similar relation at Site 2 for dry matter accumulation and cumulative ET (Fig. 3). Two years of data were combined for the regression analysis of BL (1993 and 1994) and OPH (1995 and 1996). Slope of the regression line was 24.5 kg ha^{-1} mm^{-1} for BL and 35.8 kg ha^{-1} mm^{-1} for OPH.

Total ET for OPH, fallow ET, and precipitation for 1995 and 1996 are shown in Fig. 4a and 4b for Site 2. The 1996 growing season had 60 mm less precipitation and 350 more GDD than the 1995 season (Table 2). In 1995, OPH was cut 82 d after planting, but because of hot, dry conditions, OPH was cut at 57 d in 1996. At crop termination, OPH used 313 mm of water in 1995 and 184 mm in 1996. Accumulated precipitation at time of hay cutting was 179 mm in 1995 and 82 mm in 1996.

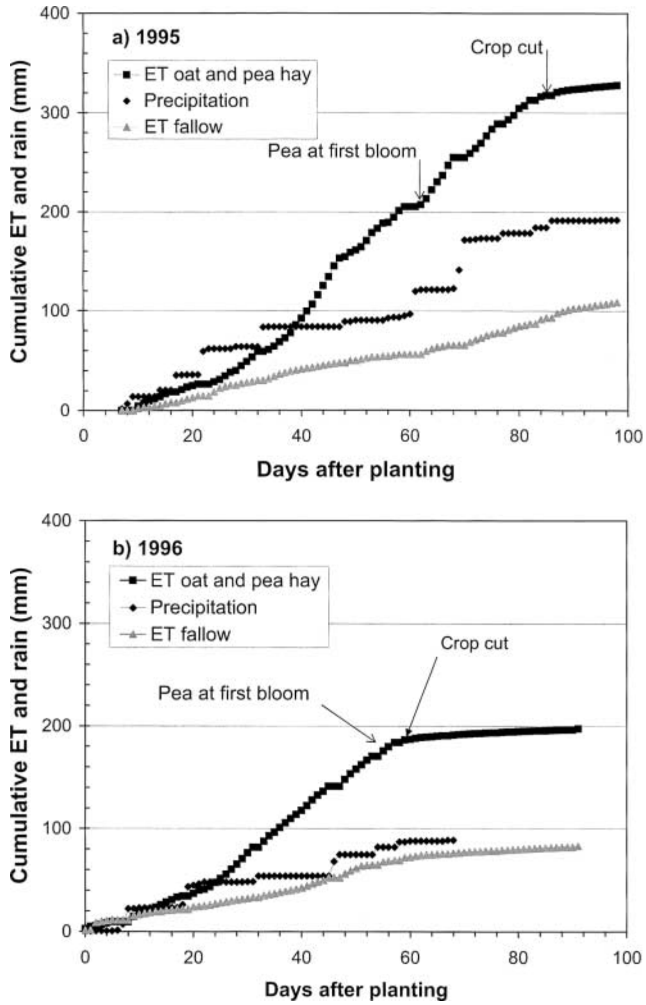

Fig. 4. Cumulative evapotranspiration (ET) for oat–pea hay (OPH), evaporation from fallow, and rain during (a) 1995 and (b) 1996 at Site 2 (precision-weighing lysimeter studies).

At 82 d in 1995, fallow lost 87 mm of soil water. In contrast, water loss from fallow was 69 mm in 1996.

Growing conditions for OPH in 1995 at Sites 1 and 2 were similar (Table 2). There were a total of 1038 GDD for 1 May through 31 July at Site 1 and 1059 at Site 2 (Table 2). Accumulation of heating units was very similar (data not shown). By 1 June, Site 1 had accumulated only 1 GDD more than Site 2 and by 1 July, Site 2 had accumulated 7 GDD more than Site 1 (cumulative GDD not shown). Precipitation for 1 May through 31 July was 187 mm at Site 1 and 214 mm at Site 2 (Table 2). However, timing of precipitation between Sites 1 and 2 was different. From 1 May to 1 June, Site 2 had received 47 mm more rain than Site 1 (Fig. 4a, cumulative precipitation not shown for Site 1). By 1 July, the difference had narrowed to 14 mm.

Oat–pea hay yield during 1995 at Site 1 averaged 5980 kg ha^{-1} (Fig. 1 and 2) and 9520 kg ha^{-1} at Site 2 (Fig. 3). We do not have a good explanation for the yield difference of 3540 kg ha^{-1}. However, we cannot discount the benefits of the timely 47 mm of precipitation between 1 May and 1 June at Site 2. Water stress early in the growing season has been shown to affect yield of pea

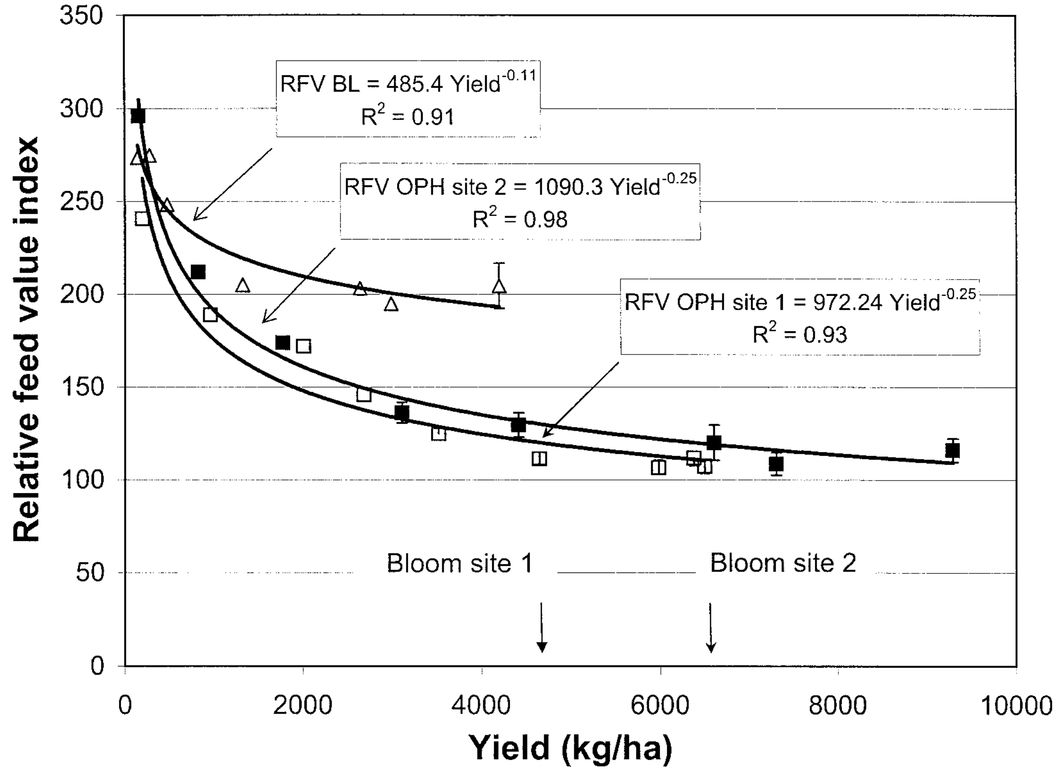

Fig. 5. Comparison of relative feed value (RFV) for oat–pea hay (OPH) at Sites 1 (soil water balance studies) and 2 (precision-weighing lysimeter studies) during 1995. For comparison purposes, RFV for black lentil grown as a green manure (BL) at Site 1 is shown. Error bars show ±1 standard deviation. Open symbols identify data points for Site 1.

(Pumphrey et al., 1979). Oat–pea hay at both Sites 1 and 2 followed fallow (Table 1).

Quality of OPH, expressed as RFV, at Sites 1 and 2 (1995) was about the same at harvest regardless of a 3540 kg ha^{-1} yield difference between the sites (Fig. 5). The RFV index simplifies interpretation of forage tests for mixed grass–legume hay. Prime hay has a RFV > 151, Number 1 hay has a RFV between 125 and 151, and Number 2 hay has a RFV between 103 and 124 (Linn and Martin, 1989). Hay quality (Fig. 5) at about 60 d following planting (corresponding to full bloom in pea) was Number 2, and this did not change appreciably as the crop matured to the soft dough stage in oat. Measurements of RFV and crop maturity provide important information with respect to timing harvest operations. Quality of forage was not sacrificed for increased biomass quantity during the time between full bloom of pea and soft dough of oat.

Chapko et al. (1991) provide several traits of companion crops grown with alfalfa in Arlington, WI. In a 3-yr trial, average RFV (calculated from ADF and NDF values presented in Chapko et al., 1991, Table 3) was 115, 133, 101, and 114 for oat, OPH, barley (*Hordeum vulgare* L.), and barley–pea forage. Chapko et al. (1991) harvested forages at about 60 d (pea plants in late bud to early flower) and concluded that OPH was the best companion crop because it had superior forage quality. The RFVs for oat and pea in Wisconsin at 60 d (Chapko et al., 1991) roughly agree with the values we present in Fig. 5 for eastern Montana.

Relative feed value of BL as hay at Site 1 (1995) exceeded that of OPH. Index value at harvest was about 200 (Fig. 5). In 1995, BL was killed shortly after pods were set in the lower portion of the plant (Table 2) rather than at full bloom. However, even at this stage of plant development, BL dry matter production was less than that of OPH. In 1995, the BL and OPH plots were seeded at about the same time (Table 2). Thus, there seems to be a trade-off between quantity and quality in respect to hay produced by black lentil and OPH. Black lentil produces a high quality hay judged by the RFV index; however, the quantity lags when compared with hay that includes a cereal. Carr et al. (1998) concluded that the cereal component of a cereal–pea intercrop contributed more to forage yield than the pea component.

SUMMARY AND CONCLUSIONS

Dry matter accumulation and water use was different under OPH and BL. The rate of plant mass accumulation was 34 and 46% greater under OPH compared with BL at Sites 1 and 2, respectively. At Site 1 (1995), cumulative ET was 207 mm for BL and 257 mm for OPH. Black lentil accumulated 2990 kg ha^{-1} (14 kg ha^{-1} mm^{-1}), and OPH accumulated 5980 kg ha^{-1} (23 kg ha^{-1} mm^{-1}) during a 75-d growing season (1995). At Site 2, average (2 yr) cumulative ET was 337 mm for BL and 249 mm for OPH. At crop termination, average (2 yr) accumulated plant mass was 7180 kg ha^{-1} (21 kg ha^{-1} mm^{-1}) under BL and 7310 kg ha^{-1} (29 kg ha^{-1} mm^{-1}) under OPH. Growing season precipitation up to hay cutting during the OPH crop years at Site 2 was 179 mm in 1995 and 82 mm in 1996, and hay yield reflected these differences. In 1995, OPH yield was 9500 kg ha^{-1}. In contrast, yield was 5100 kg ha^{-1} in 1996. During the growing seasons of 1995 and 1996, soil water loss during fallow was 87 and 69 mm, respectively.

Annual OPH produced greater quantities of plant mass per unit ET than BL. Further, the quality of OPH remained unchanged (Number 2 hay) as the crop matured from bloom in pea to the soft dough stage of oat. This crop characteristic provides a greater window of opportunity in which field harvesting of quality hay might be completed. In previous plot studies that included BL and OPH, we suggested that annual hay had a place in rotations under semiarid conditions (Pikul et al., 1997; Aase and Pikul, 2000). In this paper, we have compared water use characteristics of OPH and BL. Where the demand for high quality forage arises, OPH can provide a cropping option that efficiently uses water and may, ultimately, improve soil condition because of the inclusion of a legume in rotation. We have found, in field studies subsequent to the current, that postharvest surface and residue conditions in the year following OPH harvest are ideal for no-till planting of soybean [*Glycine max*. (L.) Merr.] (personal observation of the senior author). We think that wheat could have been no-till–planted following OPH in the current study to reduce tillage intensity. A rotation that includes OPH seems to fit the growing conditions and needs of producers in the northern Great Plains because of a regional demand for high quality forage.

ACKNOWLEDGMENTS

We thank David Harris, Jackie Couture, and Dennis Lokken, Research Technicians, USDA-ARS, for their assistance with field experiments and the Roosevelt and Sheridan County, Montana, Conservation Districts for the land that was used for this study.

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